Percentage Contributions from Atmospheric and Surface Features to Computed Brightness Temperatures

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ABSTRACT

Over the past few years, a few solid precipitation detection and retrieval algorithms have been developed and shown to be applicable for snowing clouds and blizzards. Current precipitating snow retrieval algorithms require the use of millimeter-wave radiometer observations. The millimeter-wave frequencies are especially sensitive to the scattering and emission properties of frozen particles due to the ice particle refractive index. These channels can also be used to discern information about the frozen particles above the melting layer. Passive radiometric channels respond to both the integrated particle mass throughout the volume and field of view, and to the amount, location, and size distribution of the frozen (and liquid) particles with the sensitivity varying for different frequencies and hydrometeor types. This work will show the percentage of the brightness temperature resulting from the liquid hydrometeor, frozen hydrometeor, relative humidity, and surface contributions. The focus will be on precipitating snow events and millimeter-wave frequencies however, other events and frequencies will be included in the analysis.

In order to improve retrieval algorithms it is necessary to understand the physical relationships between the brightness temperatures and the underlying cloud microphysical profile characteristics. These characteristics are complex and variable in space and time. Furthermore, it has been traditionally difficult to measure the in situ properties of frozen hydrometeors, so that rough models are employed. The properties needed for radiative transfer models include profiles of temperature, relative humidity, pressure, the amount and size distributions of all phases of clouds (water vapor, cloud water, liquid, ice, snow, graupel, etc), and ice-air-water ratios of any frozen particles. This information must then be converted to absorption, scattering, and asymmetry parameters. This conversion is relatively simple for liquid particles and more challenging for the wide variety of frozen particles.

One methodology used since the 1960's to discern the relationship between temperature profile and the brightness temperature is through the temperature weighting function profile. In this research, the temperature weighting function concept is exploited to analyze the sensitivity of various characteristics of the cloud profile, such as relative humidity, ice water path (integrated ice content), liquid water path, and surface emissivity. In our numerical analysis, we can get estimates of the contribution (in Kelvin) from each of these cloud and surface characteristics, so that the sum of these various parts equals the computed brightness temperature. Furthermore, the percentage contribution from each of these characteristics is assessed. By the nature of the weighting vector profile, these contributions can be roughly attributed to the vertical structure of

the cloud system. There is some intermingling/contamination of the contributions from various components due to the integrated nature of passive observations and the absorption and scattering between the vertical layers, but all in all the knowledge gained is useful.

This investigation probes the sensitivity over several cloud classifications, such as stratiform rain clouds, blizzards, light snow, cirrus, cumulonimbus hurricane rainbands with anvil and heavy rain, and others. Vertical atmospheric profile structures from these various cloud classifications are used as input in a robust radiative transfer model where brightness temperatures are calculated. The polydisperse gamma particle size distribution (PSD) and density parameters for rain and snow are a function of atmospheric level temperature and content in grams per meter cubed. While the different classifications do develop with different PSDs, this was a difficult control variable since there is no clear consensus in the literature. For example it could be that blizzard snow follows a log-normal size distribution, while stratiform rain follows an exponential PSD. Thus, in order to focus the investigation on the changes in cloud profile structure more exclusively, the PSD and density parameters remain fixed for the various cloud classifications tested.

The focus is on frequencies from 89 to 183 GHz, however discussions of the effects of cloud variations to frequencies as low as 10 GHz and up to 874 GHz will also be presented. The lower frequencies are more sensitive to the liquid in the cloud, while the highest frequency is more sensitive to the small sized ice particles seen in cirrus clouds. The results show that when breaking out the weighting function to assess the various internal cloud characteristics for various strengths of a blizzard cloud profile over land, the following percentages are obtained:

Case	**% from surface 89, 166, 183±7**	**% from snow 89, 166, ±7**	**% from RH 89, 166, ±7**
Clear Air	71, 34, 5%	0, 0, 0	21, 65, 94
Heavy (0.6 inch/hr melted)	57,7, 0.3	34, 81, 72	0.6, 11, 27
Medium (0.1 inch/hr melted)	68, 23, 2	15, 46, 35	13, 30, 62
Light Snow (0.025 inch/hr melted)	70, 30, 4	6, 22, 14	17, 46, 81

This table shows that nearly 60% of the brightness temperature at 89 GHz comes from the earth's surface for even the heaviest snowfall rates. On the other hand, a significant percentage of the brightness temperature comes from the snow in the cloud for 166, and 183+/-7 GHz for the heavy and medium snow rates. Qualitatively, this means that we can only use 89GHz for snowfall retrievals when we know the surface emissivity and temperature and that 166 and 183+/-7 are better channels for estimating snowfall rate. Further investigations are underway for more cloud classifications and frequencies.